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TILLAGE AND TRAFFIC EFFECT ON COTTON YIELD AND N REQUIREMENT

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Abstract

Problems associated with soil compaction have led to interest in investigating the interactive effects of tractor traffic and tillage systems on cotton production. A field study was initiated in 1987 on a Typic Hapludult with a well developed tillage pan to study the effects of traffic and tillage systems on crop performance in a wheat-cotton double-crop system. A wide frame tractive vehicle (WFTV) that allows for 20-ft. wide, untrafficked research plots was utilized to double-crop cotton "McNair 220" with wheat "Coker 9733'. The experimental design was a split-plot with 4 replications. Main plots were: 1) conventional traffick and 2) zero-traffic. Subplots were tillage systems for cotton: 1) complete surface tillage without subsoiling, 2) complete surface tillage and annual in-row subsoiling (16-inch depth), 3) complete surface tillage with one time only complete disruption of tillage pan, and 4) no surface tillage, but planted with in-row subsoiling (strip-tillage). An additional split treatment of 4 N rates (0, 40, 80, and 120 lb N/A) was added in 1990. Late planting limited seed cotton yields in 1987 and 1988. Neither traffic nor tillage had an effect on yields in 1987 or 1989. There was a significant traffic X tillage interaction on seed cotton yield in 1988. In-row subsoiling resulted in maximum seed cotton yield (1580 lb/A) in zero-traffic plots and lowest yield (1140 lb/A) in trafficked plots. In 1990, both seed cotton yield and total N uptake was increased with conventional traffic. Neither tillage system nor N application rate had a significant effect on seed cotton yield. Results indicate that both traffic and tillage system effects are strongly dependent on weather conditions during the growing season. Tractor traffic influenced cotton response to the tillage system and had both positive and negative effects on yield.

Introduction

The formation of tillage pans due to soil compaction has been recognized as a possible limitation for cotton production, especially on sandy Coastal Plain soils of the Southeast. A number of methods for alleviating soil compaction, including deep plowing, subsoiling, chiseling, crop rotation, and controlled traffic, have been reviewed by Bowen (1981). Dumas et al. (1973) evaluated systems utilizing controlled traffic and deep tillage (subsoiling) for cotton production. They found that deep tillage, regardless of traffic, resulted in larger cotton plants. Without deep tillage, controlled traffic resulted in a 9% increase in plant height. Both deep tillage and controlled traffic were necessary to obtain maximum yield (4214 lb/A seed cotton).

Williford (1982) found that cotton yield was significantly increased with controlled traffic beds and suggested that subsoiling every year was unnecessary with controlled traffic systems. In addition, wheel traffic has been shown to reduce root pod growth in peanuts (Gardner et al., 1987), and reduce forage production in alfalfa (Rechel et al., 1987; Meek et al., 1988). However, Reeves et al. (1990) found that traffic increased yields in soybeans with in-row subsoiling, while Voorhees et al. (1985) found that wheat yield was increased with wheel traffic in a dry year.

Research conducted on controlled traffic has focused on interactions with deep tillage such as subsoiling. There is also a need to investigate tillage systems, including conservation cropping systems, that utilize controlled traffic and compare them to conventionally trafficked tillage systems. The USDA-ARS National Dynamics Laboratory has recently begun research utilizing a wide frame tractive vehicle (WFTV) designed to allow for 20-ft. wide, untrafficked research plots. A detailed description of the vehicle and its capabilities has been published by Monroe and Burt (1989). Utilization of the WFTV allows for the use of various tillage systems in a zero-traffic environment.

A wheat-cotton double-cropping system was chosen to efficiently utilize the WFTV's research capabilities. The development of early maturing cotton and wheat cultivars has made a wheat-cotton double-crop a feasible alternative in the Southeast (Baker, 1987). The wheat-cotton system was chosen because both wheat and cotton respond to deep tillage on compactible soils, and double-cropping them provides an opportunity for research on both a fibrous (wheat) and tap-rooted (cotton) crop. Results from the cotton crop only are reported here.

Preliminary results from this experiment indicated that N fertility may also be affected by tillage and traffic. The level that the soil is compacted and the area that roots are able to explore in the soil profile can affect the N application efficiency (Jenkinson et al., 1985). The tillage system used will also strongly affect fertilizer N utilization in cotton. Factors such as soil moisture and temperature (which are changed with different tillage practices) will lead to great changes in the N efficiency (Jansson and Persson, 1982). Therefore, additional research was initiated in 1989 to identify the effects that tillage and traffic will have on the N fertilizer requirement for cotton.

Materials and Methods

A field study was initiated in June of 1987 at the Alabama Agricultural Experiment Station, Auburn University, Agricultural Engineering Research Farm at Shorter, AL. Cotton was grown in a double-cropping system with wheat (only cotton data is reported here). The soil is a Cahaba-Wickham-Bassfield sandy loam complex (Typic Hapludult). Cation exchange capacity (C.E.C.) and organic matter content for the test site averaged 6.31 meq/100 g, and 1.19 %, respectively. The site has a well developed 3-to-6-inch thick hardpan from 8 to 12 inches deep. To reduce variation, an effort was made to form a uniform hardpan at a depth of 8 inches by running a motor grader repeatedly in plowed furrows incrementally across the experiment site.

The experiment design was a split-plot with 4 replications. Main plots (20-ft. wide and 600-ft. long) were: 1) conventional traffic and 2) zero-traffic. Main plots were split into subplots (120-ft. long) of tillage systems: 1) complete surface tillage without subsoiling (not SS), 2) complete surface tillage and annual in-row subsoiling to 16-inch depth (SS prior cotton), 3) complete surface tillage with one-time only complete disruption of tillage pan (initial SS), and 4) no surface tillage but planted with in-row subsoiling (strip-tillage). Complete surface tillage consisted of

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disking, chisel plowing (8-inch depth), disking, and field cultivation. The one-time only complete disruption of the tillage pan was accomplished by subsoiling to a 20-inch depth on 10 inch centers, using a V-ripper in November, 1987. The strip-tilled cotton was planted into wheat stubble with a KMC in-row subsoiler planter. In 1990, the tillage subplots were split into sub-subplots (28.5-ft. long) of four N rates. The N rates were 0, 40, 80, and 120 lb N/A, creating a split-split-plot design.

Cotton "McNair 220", was planted on 30-inch rows, at 90,000 seed/A, as close to 1 June as possible (equipment problems delayed cotton planting in 1989 and 1988). On the conventionally trafficked plots tillage operations were done with the WFTV. A 4440 John Deere tractor or a Hi-boy sprayer was driven through the plots to simulate traffic that would have been applied with each operation. All operations were set up to be done with 4 row equipment. Application of 34 lb N/A at planting and 76 lb N/A at first square was made each year through 1989. In 1990, application of 20 lb N/A as NH_4NO_3 was made at planting to all but the 0 N rate plots. The remaining N fertilizer for each N rate was applied broadcast at first square.

Subplot and sub-subplot treatments were imposed on cotton only. The complete complement of tillage treatments were first imposed during the 1988 growing season. Recommended cultural practices for insect and weed control were used throughout the season on all plots. Cotton was hand picked for yield from 100 ft. of row in 1987 through 1989, and from 40 ft. of row in 1990 on approximately November 1 of each year. Plant samples were taken from 10 ft. of row for dry matter determination.

In 1990, plant and seed samples were analyzed for N content and combined for total plant N uptake. Because of variability of soil type and weed control problems in the fourth replicate, only three replications were used for analysis in the 1990 growing season.

Results and Discussion

Cotton Yield

Yield was limited in 1987 and 1988 due to late planting date of cotton. In 1987, plant growth was increased with zero-traffic, especially in the early portion of the growing season, but had no effect on seed cotton yield (data not shown). In 1988, there was a significant traffic X tillage interaction effect on seed cotton yield (Figure 1). The SS prior to cotton treatment resulted in maximum yield in the zero-trafficked plots (1580 lb/A), but lowest yield in the trafficked plots (1140 lb/A). Within zero-trafficked plots, the initial SS treatment (subsoiling 20 inches deep on 10-inch centers prior to first wheat crop) reduced yields compared to in-row subsoiling at planting. In trafficked plots, however, the initial SS treatment increased seed cotton yield compared to SS prior to cotton.

The 1989 growing season had a very cool and excessively wet spring with only short periods of water stress for the cotton during the growing season. In this year, there were no significant differences between tillage (P = 0.24) and traffic (P = 0.27) treatments for seed cotton yield (data not shown). Maximum yield was achieved in the zero-trafficked and not SS plots (1625 lb/A). Strip-tillage resulted in the lowest yields for both the trafficked and zero-trafficked plots, with an average of 1252 lb/A. This non-significant trend may have been caused by reduced stand vigor due to cool and wet conditions in the strip-tillage plots.

The 1990 growing season was very dry, causing water stress in the cotton plants throughout most of the growing season. In this year, a significant decrease in both seed and lint production resulted from the zero-traffic treatment, with 1338 and 1213 lb seed cotton/A for traffic and zero-traffic, respectively. Similar results have been reported by Voorhees (1985) for spring wheat during a dry growing season. They reported a 53% increased in wheat yield above controlled traffic treatments. Yield reductions in soybeans have also been reported for controlled traffic systems in dry years (Reeves et al., 1990; Voorhees et al., 1989). While no differences were found between the tillage treatments for seed cotton yield, seed production was significantly affected by tillage (Figure 2), with strip-tillage having significantly higher seed yield than SS prior to cotton when averaged over traffic treatment (787 and 662 lb/A, respectively). Similar non-significant trends were seen in cotton lint production. Seed yield was also increased with traffic, with 763 and 707 lb/A (P = 0.10) for traffic and zero-traffic, respectively.

Total dry matter production at harvest was highest for the not SS plots (Figure 3). A significant reduction in total dry matter occurred when complete surface tillage was combined with subsoiling, with 2659 lb/A dry matter compared to 3075 lb/A with and without subsoiling, respectively. No significant difference occurred between the not SS and the strip-tillage treatments.

Total dry matter was significantly increased with increasing fertilizer N application (Figure 4), but no significant difference in seed or lint production was seen. Percent lint of seed cotton was significantly decreased with increasing fertilizer N application, with 42.7% with no N application and 41.1% with 120 lb N/A application. Similar N response to lint percentage was reported by Perkins and Douglas (1965). Consequently, while cotton seed production tended to increase with increased application of N, lint production was highest for the 0 lb/A N application (1.12 and 1.09 bales/A with 0 and 120 lb N/A application, respectively). This indicates that the beneficial response of cotton to fertilizer N application may be limited under extremely dry growing conditions.

Nitrogen Uptake

Fertilizer N uptake by the cotton plants in 1990 was extremely limited in this dry growing season with an average fertilizer N uptake efficiency of 17% for the 120 lb N/A rate. Increasing rate of fertilizer N significantly increased total N uptake in the plant, with most of the differences in plant N being accounted for in the stalks (Figure 5). Fertilizer N application had very little effect on seed N content, with only the 120 lb N/A rate having significantly higher N content in the seed than with no fertilizer N application.

Total N uptake was significantly increased with tractor traffic, increasing from 65 to 69 lb N/A for the trafficked and zero trafficked treatments, respectively. While N uptake in the stalk had the greatest response to differences in N rate application (Figure 5), no differences in stalk N uptake was found for tractor traffic. This indicates that differences in N uptake due to traffic were most likely due to differences in dry matter production, especially seed production, between the treatments than to differences in N availability.

N uptake was significantly affected by tillage treatment, with not SS having the greatest N uptake (Figure 6). The Not SS treatment resulted in 72 lb N/A compared to 62 lb N/A for the SS prior to cotton treatment. Most of these differences can also be explained by differences in dry matter production between treatments. However, some difference due to N availability were evident in the strip-tillage treatment. While stalk dry matter production was not significantly different for the strip-tillage treatment compared to the not SS, N uptake in the stalks was significantly reduced (Figure 7). This indicates that the increased organic matter in the strip-tillage plots may have tied up available N and resulted in some reduction in N uptake.

Conclusions

Results from this study indicate that the effect of tillage and tractor traffic on cotton production is variable depending on the moisture condition during the growing season. In years of below normal rainfall during the growing season, strip-tillage was found to maintain seed cotton yields near the maximum, even though the effect of subsoiling was variable with both beneficial and detrimental effects occurring. Zero-traffic resulted in a non-significant increase in seed cotton yield in most years, but was found to significantly reduce seed cotton yield and total N uptake in extremely dry years. Fertilizer N application had no effect on cotton yield in a extremely dry growing season, indicating that the beneficial effect of fertilizer N may be limited under these conditions. Plant uptake of N was affected by tillage system, with most of the differences being explained with differences in dry matter production. However, results indicate that reduced N uptake in the strip-tillage plots may have resulted from reduce N availability in these plots.

References

1. Baker, S. H. 1987. Effect of tillage practices on cotton double cropped with wheat. Agron J. 79:513-516.

2. Bowen, H. D. 1981. Alleviating mechanical impedance. p. 21-53. In Arkin, G. F. and H. M. Taylor (ed.) Modifying the root environment to reduce crop stress. Amer. Soc. of Agric. Eng., St. Joseph, Michigan.

3. Dumas, W. T., A. C. Trouse, L. A. Smith, F. A. Kummer, and W. R. Gill. 1973. Development and evaluation of tillage and other cultural practices in a controlled traffic system for cotton in the Southern Coastal Plains. Trans. ASAE 16:872-876.

4. Gardner, F. P., A. Selamat, and R. S. Mansell. 1987. Soil penetrometer resistance and peanut responses to tractor-wheel compaction in sandy soil. Soil and Crop Sci. Soc. FL. Proc. 46:112-117.

5. Jansson, S. L., J. Persson. 1982. Mineralization and immobilization of soil nitrogen. p. 229-252. In F. J. Stevenson et al. (ed.) Nitrogen in agricultural soils. Agron. Monogr. 22. ASA and SSSA, Madison, WI.

6. Jenkinson, D. S., R. H. Fox, and J. H. Rayner. 1985. Interactions between fertilizer nitrogen and soil nitrogen--the so-called 'priming' effect. J. Soil Sci. 36:425-444.

7. Meek, B. D., E. A. Rechel, L. M. Carter, and W. R. DeTar. 1988. Soil compaction and its effect on alfalfa in zone production systems. Soil Sci. Soc. Am. J. 52:232-236.

8. Monroe, G. E. and E. C. Burt. 1989. Wide frame tractive vehicle for controlled traffic research. Applied Engineering in Agriculture 5:40-43.

9. Perkins, H. F., and A. G. Douglas. 1965. Effects of nitrogen on the yield and certain properties of cotton. Agron J. 57:383-384.

10. Rechel, E. A., L. M. Carter, and W. R. DeTar. 1987. Alfalfa growth response to a zone-production system. I. forage production characteristics. Crop Sci. 27:1029-1034.

11. Reeves, D. W., J. A. Droppers, and J. B. Powell. 1990. Controlled traffic: influence of tillage requirements for corn and soybean. p. 323. In Agronomy Abstracts, ASA, Madison, WI.

12. Voorhees, W. B., S. D. Evans, and D. D. Warnes. 1985. Effect of preplant wheel traffic on soil compaction, water use, and growth of spring wheat. Soil Sci. Soc. Am. J. 49:215-220.

13. Voorhees, W. B. 1989. Root activity related to shallow and deep compaction. In: W. E. Larson, G. R. Blake, R. R. Allmaras, W. B. Voorhees and S. C. Gupta (Editors), Mechanics and related processes in structured agricultural soils. Kluwer Academic Publishers, Norwell, MA, (U.S.A.), pp.173-186.

14. Williford, J. R. 1982. Residual effect of subsoiling in a controlled-traffic system. ASAE paper no. 82-1044.

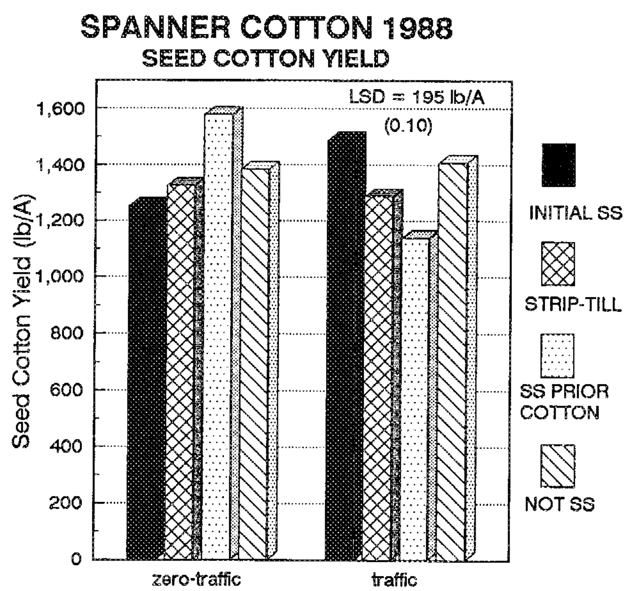

Figure 1. Seed cotton yield as affected by traffic and tillage in a wheat-cotton double-crop system, 1988. Not SS = conventional surface tillage; SS prior cotton = conventional surface tillage with in-row subsoiling; Initial SS = one time only complete disruption of hardpan; and Strip-till = no-till with in-row subsoiling into wheat stubble.

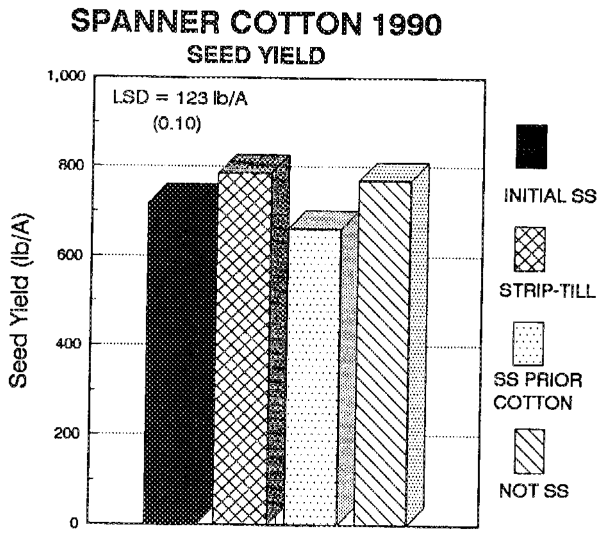

Figure 2. Yield of cotton seed as affected by tillage system in a wheat-cotton double-crop system, 1990. Not SS = conventional surface tillage; SS prior cotton = conventional surface tillage with in-row subsoiling; Initial SS = one time only complete disruption of hardpan; and Strip-till = no-till with in-row subsoiling into wheat stubble.

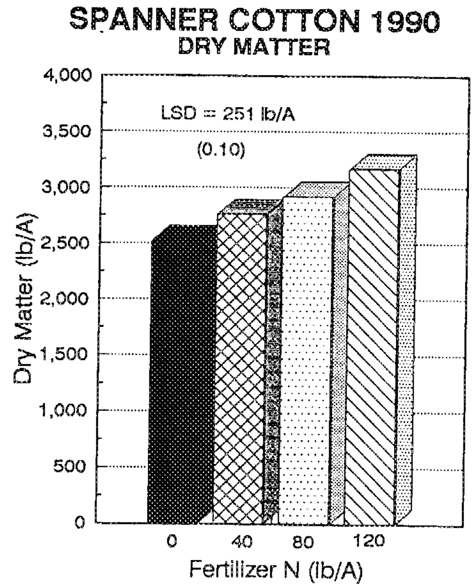

Figure 4. Cotton dry matter production as affected by fertilizer N application in a wheat-cotton double-crop system.

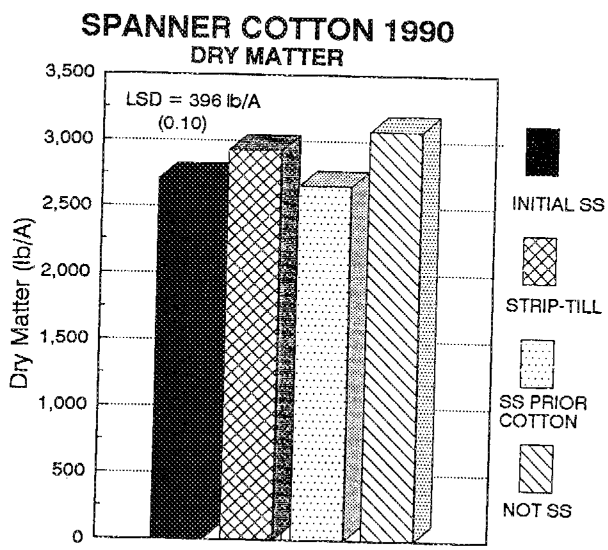

Figure 3. Cotton dry matter production as affected by tillage in a wheat-cotton double-crop system, 1990. Not SS = conventional surface tillage; SS prior cotton = conventional surface tillage with in-row subsoiling; Initial SS = one time only complete disruption of hardpan; and Strip-till = no-till with in-row subsoiling into wheat stubble.

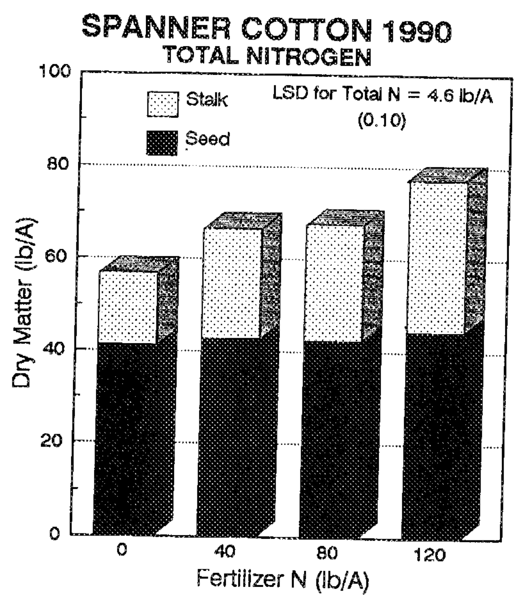

Figure 5. Total N uptake in cotton as affected by fertilizer N application. Stalk = N uptake in cotton stalk, Seed = N uptake in the cotton seed.

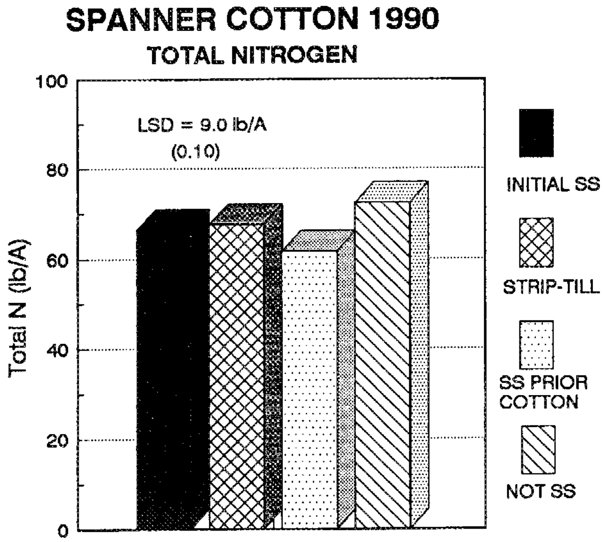

Figure 6. Total N uptake by cotton as affected by tillage system in a wheat-cotton double-crop system, 1990. Not SS = conventional surface tillage; SS prior cotton = conventional surface tillage with in-row subsoiling; Initial SS = one time only complete disruption of hardpan; and Strip-till = no-till with in-row subsoiling into wheat stubble.

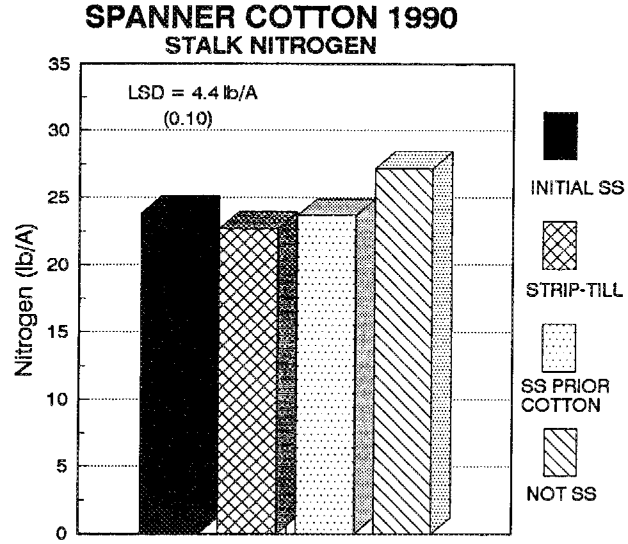

Figure 7. Cotton stalk N uptake as affected by tillage in a wheat-cotton double-crop system, 1990. Not SS = conventional surface tillage; SS prior cotton = conventional surface tillage with in-row subsoiling; Initial SS = one time only complete disruption of hardpan; and Strip-till = no-till with in-row subsoiling into wheat stubble.